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Preface

Cellular automata are discrete models that are simple to describe, yet rich in their behavior, which makes them attractive for theoretical studies. A hugely popular example is John Conway's *Game-of-Life*. Cellular automata reflect several fundamental aspects of the physical world, such as massive parallelism, locality of interactions and uniformity of the rules in space and time. Hence they are an ideal choice to model and simulate real world phenomena. Important physical constraints such as time reversibility and conservation laws can also be obtained by carefully choosing the local update rule. Very simple cellular automata are known to admit universal computation, and cellular automata provide an excellent platform to investigate massively parallel computation under realistic constraints imposed by nature. Initially conceived by John von Neumann in the late 40s to study self-reproducing universal systems, cellular automata form one of the oldest and most established fields of natural computing.

Cellular automata are discrete dynamical systems that logically come up in the context of symbolic dynamics. Closely related discrete systems such as graph automata, sandpile models and tiling systems are often studied using similar methods. These areas are becoming increasingly popular as witnessed, for example, by the large number of conferences and workshops organized about them in recent years. The papers in this volume provide a broad view of the recent developments in the theoretical aspects of cellular automata and related discrete dynamical systems. The high number and quality of papers in the volume is yet another demonstration of the vitality of the field.

This special issue was initiated at the 15th International Workshop On Cellular Automata and Discrete Complex Systems (AUTOMATA 2009), held on October 10th–12th, 2009, in São José dos Campos, Brazil. The issue was decided not to be limited only to papers presented in the workshop, but a public call for papers was made to get the broadest possible view of the field. Rigorous refereeing of the submitted papers lead to the selection of eleven articles presented here.

The first three papers of this issue are about topological dynamical aspects of cellular automata. The article by M. Delacourt et al. investigates directional dynamics in cellular automata. This concept refers to the dynamics as seen by a moving observer. In particular, the paper studies variants of sensitivity relative to an observer that moves with a speed that is not necessarily constant. For example it is shown that — surprisingly — there exists a cellular automaton that appears sensitive to initial conditions to any observer moving at constant speed, but is equicontinuous along a parabola in the space-time.

The paper by S. Capobianco looks at cellular automata as dynamical systems under Besicovitch and Weyl topologies instead of the usual product topology. These topologies are based on translation invariant pseudo-distances which makes them attractive in the context of cellular automata. This point of view has been previously used in the setting of one-dimensional cellular automata, but Capobianco generalizes the approach to higher dimensional cases, and even to cellular automata on arbitrary finitely generated groups.

The paper by M. Pivato introduces the concept of general symbolic dynamical systems, that include cellular automata but also many other systems on discrete space. He studies the connection between expansivity and the growth rate in the dependency network. It is shown that, roughly speaking, if the dependency network grows super-linearly then the system cannot be positively expansive. The result generalizes the well-known fact that a two- or higher dimensional cellular automaton cannot be positively expansive.

The next three papers are related to the concepts of simulation and universality in cellular automata. The paper by K. Morita investigates simulations by reversible one-dimensional cellular automata, with the goal of reducing the number of states. New, state efficient simulations of arbitrary reversible Turing machines are provided that improve previously known results, and a 24-state reversible cellular automaton is constructed that can simulate any cyclic tag system. Reversibility is guaranteed by working in the framework of partitioned cellular automata.

The two papers by M. Delorme et al. develop a theory of simulations between cellular automata that is based on comparing their space-time diagrams up to rescaling. In the first paper, an axiomatic theory of bulking is discussed, where the axioms state necessary conditions required in reasonable definitions of simulations between cellular automata. The classical notion of intrinsic simulation is considered and shown to satisfy the axioms. The second paper proposes three

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variants of CA bulkings using rescalings of space-time diagrams, and the subautomaton and the quotient relations and their combinations. The paper gives a detailed study of the structure of the obtained simulation quasi-orders. The two papers together form a solid foundation on the study of intrinsic simulations and universality in cellular automata.

E. Goles et al. study communication complexity in one-dimensional cellular automata, where the amount of communication refers to the minimum amount of information that needs to be exchanged between the left and the right halves of a configuration to compute some desired value. In the present paper the value to be computed characterizes whether the middle cells reach some fixed pattern in the cellular automaton evolution. Classes of cellular automata with low and high communication complexity are found, and connections between sensitivity characteristics and the communication complexity are established.

The paper by M. Kutrib and A. Malcher also concerns the amount of communication in cellular automata and iterative arrays. The authors study the computational power of real and linear time iterative arrays and cellular automata when the inter-cell communication bandwidth is bounded by some constant which is independent of the number of states. A double hierarchy is obtained with respect to the dimension of the iterative array and the allowed bandwidth.

The last three papers in the special issue concern dynamical systems on finite graphs. The paper by C. Barrett et al. investigates stochastic dynamics on finite undirected graphs, motivated by applications on dynamics in social networks such as, for example, the spread of epidemics or the propagation of influence. The problems of reachability, predecessor existence and most likely successor are found relevant for the applications. The present paper studies their computational complexity and gives results for both synchronously updated systems and sequentially updated systems.

The paper by J.-B. Rouquier et al. investigates a particular stochastic dynamical system on finite undirected graphs. The system considered is the minority function applied asynchronously on a single cell at each time step, where the active cell is chosen randomly and uniformly from the graph. The active cell simply changes its state to the one that is in minority among its neighbors. These and similar processes have many applications, and interesting theoretical questions arise. The present paper investigates how the the convergence time depends on the type and size of the underlying graph.

The article by C. Mejía and J.A. Montoya contains computational complexity results on sandpiles over finite graphs. These have attracted attention as a model of the self-organized criticality. The considerations are restricted to families of graphs with bounded degrees. Hardness results are obtained for several computational problems, and it is shown that many naturally arising questions can be reduced to the problem of computing the sums of critical configurations.

I would like to thank all the authors for their contributions. I extend my sincere thanks to the referees for their invaluable help in selecting the papers.

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